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BURNING RATE CONTROL FACTORS

IN SOLID PROPELLANTS

Ninth Quarterly Technical Summary Report

For the Period 1 January 1961 to 31 March 1961

Aeronautical Engineering Report No. 446-1

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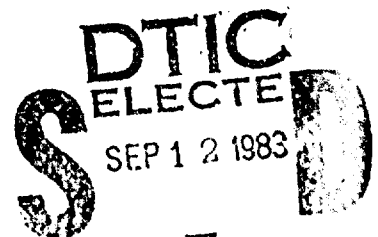
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I. INTRODUCTION

During the past quarter a technical report was published which summarizes the work done under this program in determining the effects of oxidizer particle size on propellant burning rates.*

Experimental work has proceeded along a number of lines. Some of these are intended to extend the results reported during the particle size studies, while others involve newer aspects of propellant burning rates. No significant amount of data has been obtained as yet, but it is expected that at least preliminary results will be available from each program for inclusion in the next quarterly report.

The various programs currently underway are described briefly below:

(1) Effects of oxidizer particle size are being studied in polysulfide propellants with higher oxidizer loading than those used earlier. Polysulfide propellants used in this program heretofore contained 65 per cent ammonium perchlorate by weight. Propellant is now being formulated with 75 weight per cent oxidizer in bimodal particle size distributions. The use of unimodal distributions at greater than 65 per cent is being considered, but such propellants would require extrusion casting techniques for which we are not at present equipped.

(2) As an extension of earlier work, oxidizer particle size effects are being studied in propellants formulated with more recently developed binders. A polybutadiene-acrylic acid binder, obtained from the Thiokol Chemical Corporation, is being used in a new series of propellants with controlled particle size distributions. Burning rates as a function of particle size will be reported in the next report.

A comprehensive program designed to study the relation between binder type and burning characteristics is contemplated. It is believed that such a study would elucidate the role of the binder in the burning process.

(3) A joint program is underway between Picatinny Arsenal and Princeton University to study propellant burning rates at high pressures, that is, pressures between 1000 and 20,000 psi. It is anticipated that propellant will be formulated at Princeton and burning rates measured at Picatinny. The object of the program will be to determine effects of propellant composition, fuel type and oxidizer particle size at these pressures. Initial testing is underway to determine optimum propellant strand shapes and inhibitor compositions for burning at high pressures.

(4) A program has been initiated to study burning rates of aluminumized propellants. The primary objective of this work is to determine burning rates as a function of aluminum concentration, aluminum particle size, oxidizer particle size, and fuel type. A secondary objective is to gain an insight into the behavior of the aluminum particles in the combustion zone.

*Bastress, E. Karl, "A Technical Report on the MODIFICATION OF THE BURNING RATES OF AMMONIUM PERCHLORATE SOLID PROPELLANTS BY PARTICLE SIZE CONTROL," Aeronautical Engineering Report No. 536, Princeton University, March, 1961

The large number of variables in a three component propellant system, as compared to a simple fuel-oxidizer system, complicates this program considerably. Therefore, initial testing will be directed at determining the relative importance of the variables, with controlled studies of individual variables to follow.

Initial work will be carried out with either polysulfide or polybutadiene-acrylic acid propellants containing unimodal particle size distributions of ammonium perchlorate and small concentrations of aluminum.

II. DEVELOPMENT OF PROPELLANT PROCESSING EQUIPMENT

During the past quarter considerable effort has been made to improve techniques and apparatus for propellant processing and strand burning rate measurement. Propellant mixing is carried out as reported earlier. Double-arm sigma-blade mixers are used with one pint and three pint capacities. Oxidizer is introduced during mixing by vibratory feeders and the operation is remotely controlled and observed through a closed circuit television system.

New apparatus has been manufactured for vacuum casting of uncured propellant. This apparatus is shown in Figure 1. The propellant mold, whether it be a simple block mold or a motor casing, is placed on a table which is vibrated by an electro-magnetic vibrator. The table is isolated from the base of the apparatus by vibration mounts. The table and mold are enclosed in a bell jar which is sealed against the base. Connections for driving and water-cooling the vibrator and evacuating the bell jar are made through the base.

Propellant is introduced through the top of the bell jar by means of a casting funnel and a slit deaerator. These parts are shown in Figure 2. The funnel is machined from aluminum and can be preheated for use with high viscosity propellants. Its mass is such that little change in temperature occurs during casting. The funnel is sealed by means of a plug which is removed after the funnel has been filled with propellant and the bell jar evacuated. The deaeration slit is sealed in the bell jar tubulature by a rubber stopper and the funnel is sealed to the slit by an O-ring. A variety of slit widths are available.

This apparatus has proven to be convenient and effective for obtaining sound propellant castings. It is flexible in that various shapes can be cast by merely changing the propellant mold.

During the past year a new strand burner has been developed which incorporates improvements in performance and operating procedures over previously used equipment. After some modifications of the original design, this new burner is now in operation and is being used for all strand burning rate measurement.

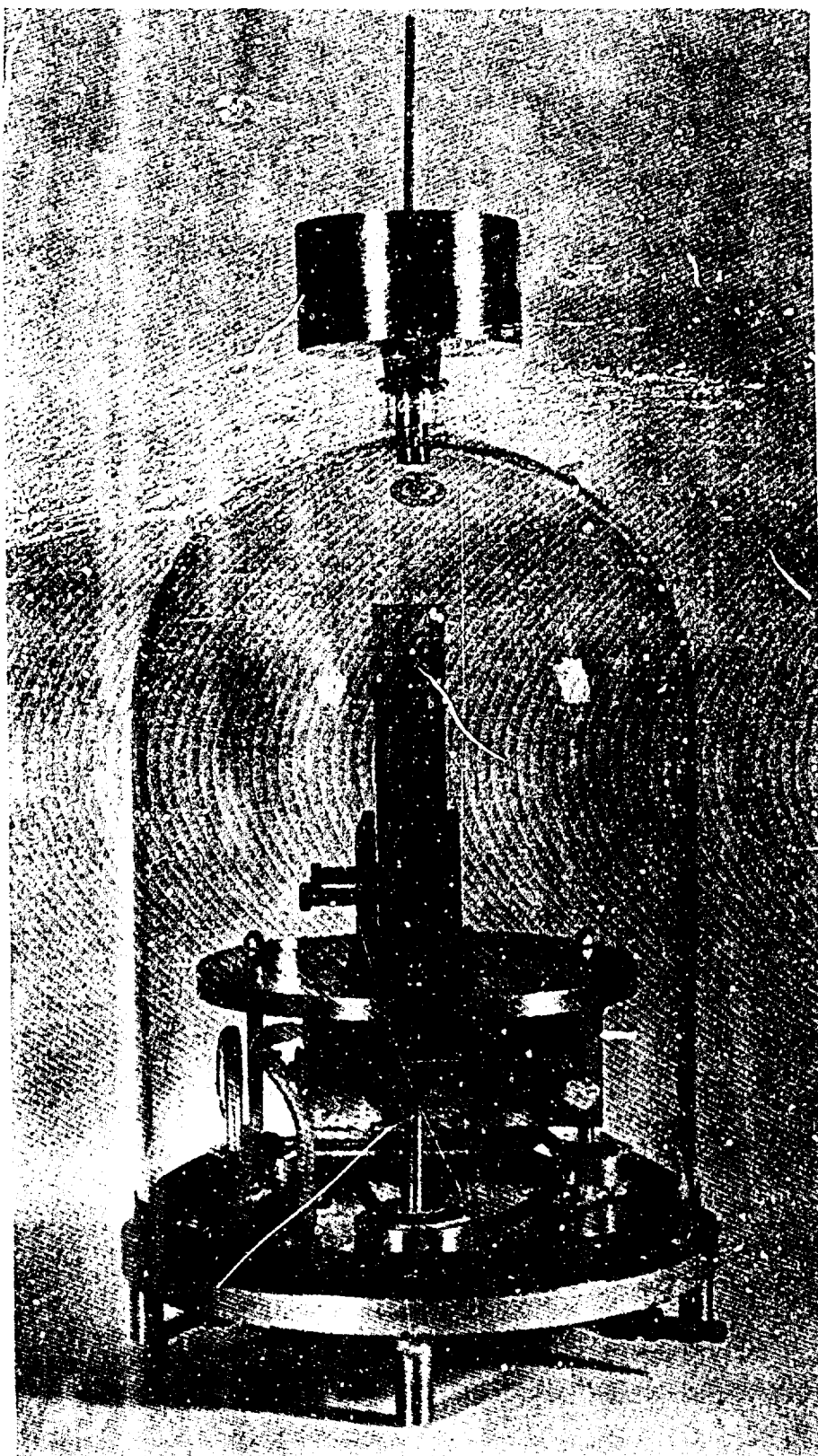
The strand burner is shown in Figure 3 with a propellant strand in place and the burner closure shown removed. Some of the operating features of this burner are enumerated as follows:

(1) The burner incorporates the upward flow of nitrogen purge gas around the strand during burning which has been found to be advantageous in earlier work at Princeton (See Report No. 446-e). This upward flow increases the precision of burning rate measurements and reduces or eliminates the need for inhibitor coatings on the strands. The nitrogen flow rate is adjusted so that its velocity is approximately equal to that of the propellant gases emerging from the combustion zone. However, the magnitude and precision of burning rates is found to be relatively insensitive to variations in nitrogen velocity from this condition.

(2) The burner incorporates means for operating at temperatures between -100 and 300 degrees Fahrenheit. The main burner body and a heat exchanging coil through which the purge gas enters are immersed in an insulated bath. Electric immersion heaters allow operation at elevated temperatures, and reduced temperatures are achieved through the use of ice or dry ice and low freezing liquids.

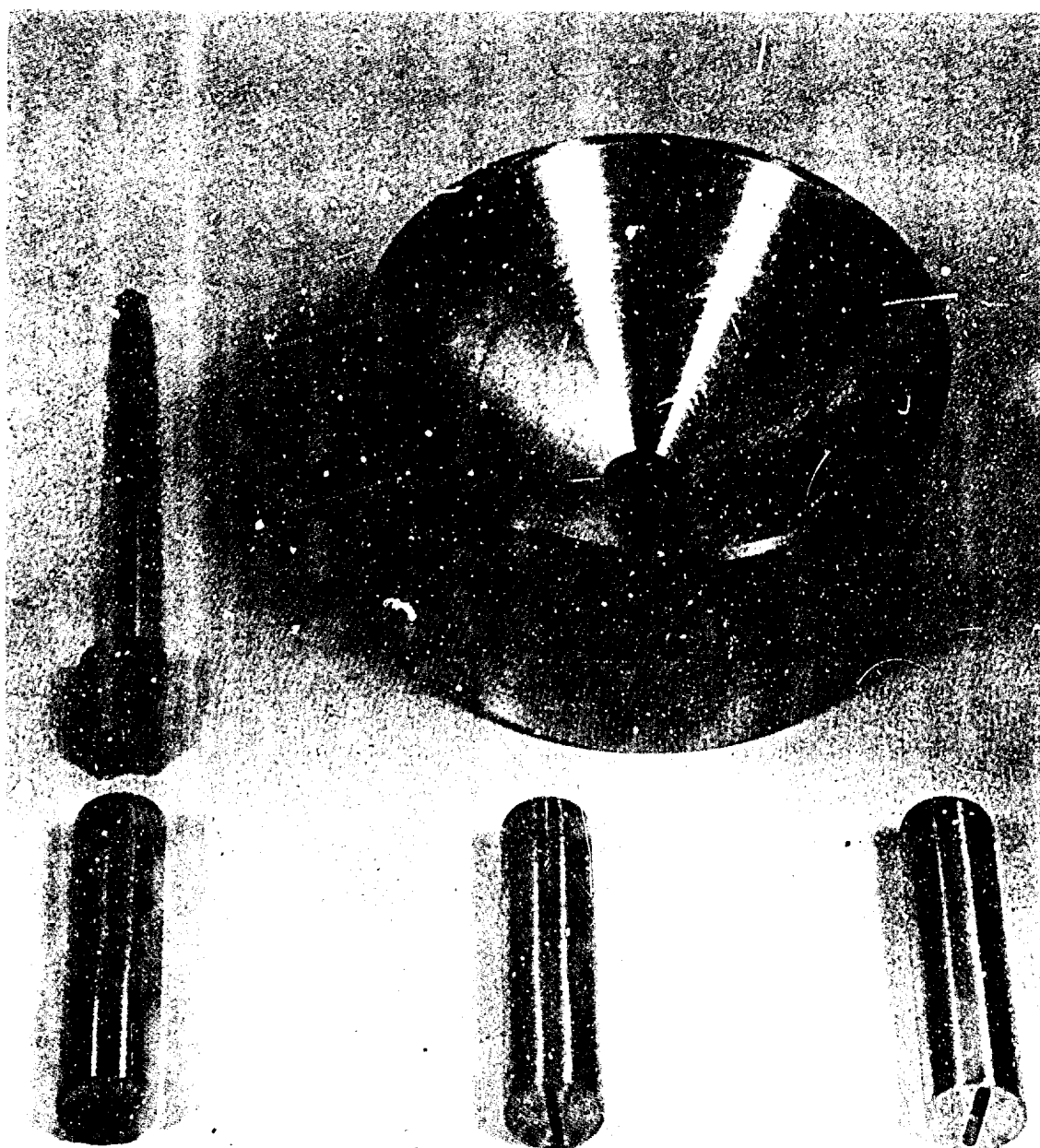
(3) The design of the strand burner is such that the operation is rapid. Propellant strands which have been drilled and wired are mounted quickly in the burner body and electrical continuity is checked before the closure is assembled. These design features allow burning rate measurements at the rate of five or more per hour.

With these improvements in apparatus, the experimental program has become a comparatively smooth operation, and it is anticipated that propellant burning rate studies will proceed rapidly during the next quarter.

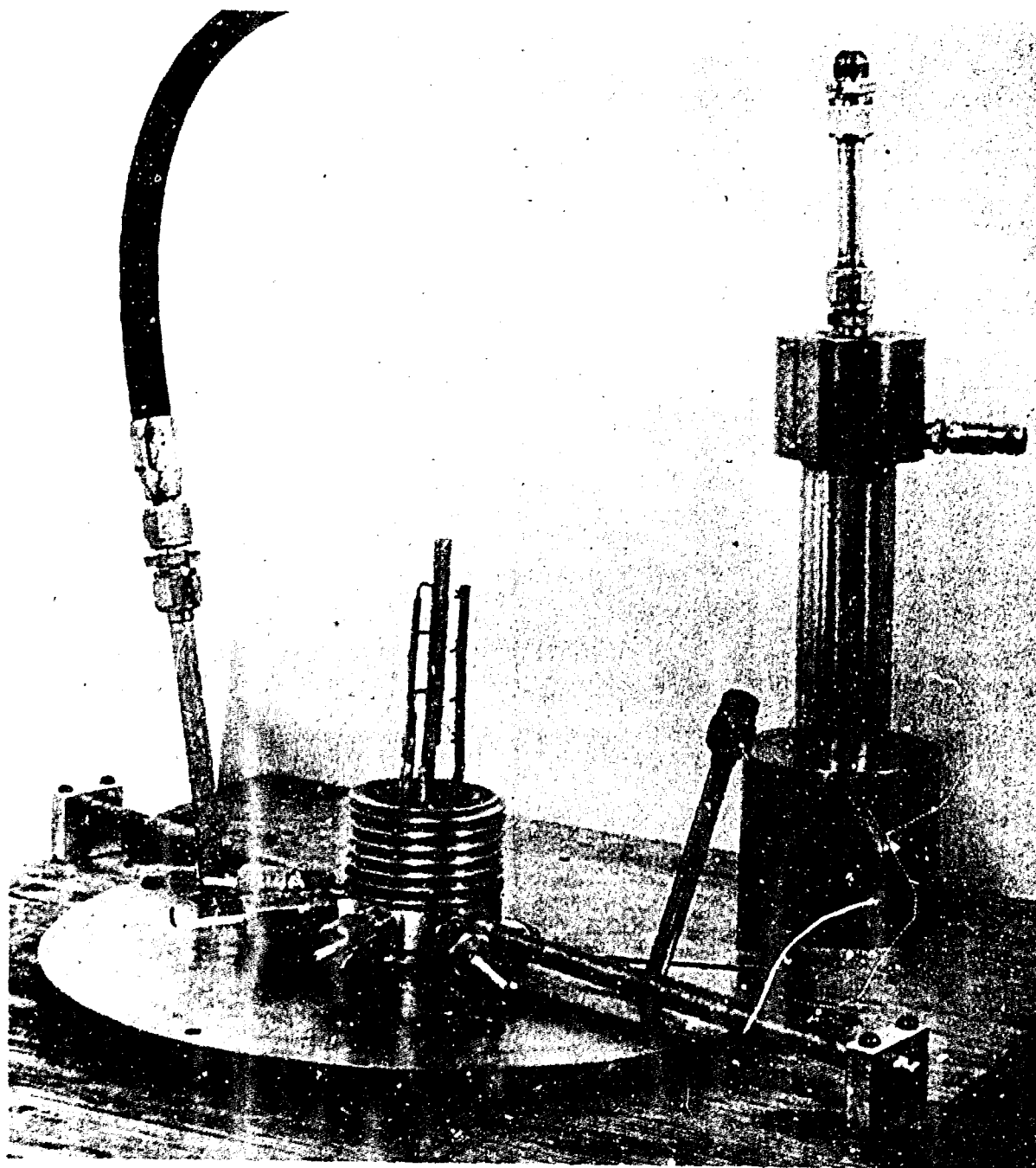


VACUUM CASTING APPARATUS

FIGURE 1



CASTING FUNNEL AND DEAERATION SLITS



CHIMNEY STRAND BURNER WITH
TEMPERATURE CONTROL

FIGURE 3

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